rotation comparable to that of the Earth or *Mars*—a view supported by the great probability that the extraordinary results claimed by the long rotation could not reasonably have been brought about by tidal friction.

Long-enduring Spots on Jupiter. By A. Stanley Williams.

There are several cases on record of spots on *Jupiter* which have remained in existence for periods measured by a number of years. The first authentic instance of the kind relates to the celebrated spot which appeared in the latter half of the seventeenth century, and which may possibly be identical with the present well-known "red spot." This last-named object has been under constant observation for at least twenty years, whilst its existence can be traced for perhaps thirty or forty years more. A third instance is that of the brilliant white equatorial spot which attracted so much attention in 1880, and remained visible for at least five or six years. Such cases of extreme longevity are not only interesting in themselves, but are of extreme importance in connection with questions relating to the present physical condition of *Jupiter*.

The object of the present paper is to put on record another instance of remarkable longevity in a Jovian spot. The object in question was a brilliant white spot situated on the north edge of the great north equatorial belt. For convenience it is designated C. The following is a complete list of all the observed times of transit of this spot which have come to the writer's notice,* together with the corresponding longitudes, all uniformly expressed according to the "System II." of the late Mr. Marth's ephemerides for 1887 and 1888.† The zero meridian of this system has several times been subsequently shifted 10°, in order to make it correspond nearly with the centre of the red spot. The longitudes given here refer to the unshifted zero meridian. For the observations made by the writer, the weights attributed to them at the time have been added. These weights range from 1 (bad) to 5 (good). An additional column gives the brightness of the spot according to a uniform scale, in which eeB=most exceedingly bright, eB=exceedingly bright, vB=very bright, B=bright, mB=moderately bright, F=faint, vF=very faint, eF=exceedingly faint. The total number of transits is 153.

* The spot also appears in some of the Lick photographs of *Jupiter*, but it has not been thought necessary to measure these, the visual observations being already sufficiently numerous.

† The daily rate of rotation of this system is 870°·2700, corresponding to a period of rotation of $9^h\ 55^m\ 40^s{\cdot}63$.

Observations of Bright Spot C.

Date.	G.M.T. of Transit.	Weight.	Longitude.	Brightness.	Observer.
1885.	h m		°		
Jan. 27	11 1	...	260·1	...	Denning.
Mar. 4	10 21	...	250·3	...	"
7	7 54	...	252·6	...	"
11	11 4	...	248·8	...	"
12	6 57	...	249·9	...	"
14	8 29	...	246·1	...	"
19	7 50·3	...	(254·4)	...	Terby.
28	10 3	...	247·3	...	Denning.
31	7 32·8	...	247·3	...	Terby.
Apr. 2	9 8	...	245·4	...	Denning.
4	10 45	...	244·5	...	"
12	7 19	...	241·9	...	"
18	12 20	...	245·1	...	"
19	8 7	...	242·4	...	"
19	8 11·7	...	245·3	...	Terby.
20	13 49·7	...	239·7	...	Barnard.
23	11 23	...	241·6	...	Denning.
25	12 55·2	...	237·7	...	Barnard.
May 1	8 0	...	240·3	...	Denning.
June 1	8 33	...	234·0	...	"
3	10 18	...	237·6	...	"
13	8 19	...	226·4	...	"
20	9 11	...	228·2	...	"
1886.					
Apr. 6	7 27	...	162·4	...	"
13	8 14	...	162·6	...	"
25	8 4	...	160·9	...	"
27	9 42	...	160·7	...	"
30	7 13	...	161·5	...	"
1887.					
Feb. 26	15 45	3	93·2	B	Williams.
Apr. 8	14 9	3	81·1	"	"
16	10 46	est.	81·7	vB	"
20	13 51	3	75·1	B	"
25	13 0	3	76·2	vB	"
30	12 6	5	75·5	eB	"
May 10	10 19·5	4	74·8	"	"
14	13 39	3	76·7	vB	"

Date.	G.M.T. of Transit.	Weight.	Longitude.	Brightness.	Observer.
1887.	h m		°		
June 8	9 10·5	...	71·7	...	Terby.
10	10 45	3	69·3	B	Williams.
10	10 45·5	...	69·6	...	Terby.
15	10 0	est.	73·3	B	Williams.
17	11 36	4	71·7	,,	,,
20	9 5·5	...	71·4	...	Terby.
22	10 36	3	66·4	B	Williams.
22	10 38·5	...	67·9	...	Terby.
25	8 16·5	...	72·7	...	,,
27	9 48·5	...	68·6	...	,,
July 2	8 57·5	...	68·7	...	,,
14	8 51·5	...	66·8	...	,,
26	8 42·5	...	62·7	...	,,
1888.					
Mar. 25	14 7	3	19·7	vB	Williams.
Apr. 1	14 56	1	21·8	B	,,
3	16 33	3	21·2	vB	,,
6	13 53·5	4	15·8	,,	,,
13	14 41·7	4	17·6	eB	,,
20	15 27	5	17·7	eeB	,,
May 3	11 4	3	14·0	vB	,,
10	11 57	4	18·9	,,	,,
12	13 30	3	15·9	,,	,,
14	15 9	3	16·5	,,	,,
15	11 11	2	23·1	B	,,
19	14 17·5	3	18·0	eB	,,
20	10 10·5	3	18·5	vB	,,
24	13 25	1	17·6	,,	,,
27	10 48	3	14·0	,,	,,
June 1	9 59	4	16·3	eB	,,
3	11 38	2	16·8	vB	,,
10	12 20·5	2	15·0	,,	,,
13	9 49	5	14·5	,,	,,
22	12 13	1	14·4	B	,,
July 19	9 30	1	12·8	,,	,,
Aug. 22	7 45	est.	14·6	vB	,,
1889.					
Mar. 2	17 10	1	11·1	,,	,,
26	17 55	1	14·1	F	,,

Date.	G.M.T. of Transit.	Weight.	Longitude.	Brightness.	Observer.
1889.	h m		°		
Apr. 22	14 42	1	25·4	F	Williams.
July 4	9 56·5	3	30·9	mB	,,
6	11 29·1	2	27·6	,,	,,
21	8 43·8	2	22·9	,,	,,
30	11 8·7	1	23·2	vF	,,
Aug. 26	8 26·7	est.	21·8	,,	,,
Sept. 12	7 45	...	29·3	...	Denning.
1890.					
May 20	14 59·6	2	18·6	mB	Williams.
27	15 46·1	1	18·9	,,	,,
30	13 15	1	18·6	B	,,
July 3	11 13·3	2	17·6	,,	,,
22	11 58·2	1	22·5	vF	,,
24	13 30·4	2	19·0	F	,,
Aug. 1	10 4·5	2	17·7	mB	,,
3	11 49·8	3	22·2	,,	,,
5	12 30·2	2	23·7	,,	,,
8	10 51	1	18·6	,,	,,
15	11 37·6	3	19·3	,,	,,
30	9 0·4	1	19·3	,,	,,
Sept. 4	8 12·5	2	21·8	,,	,,
6	9 47·8	2	20·0	F	,,
8	11 21·9	2	17·4	,,	,,
16	8 3·5	3	19·5	,,	,,
Oct. 10	7 53	2	17·8	mB	,,
17	8 44·6	1	20·0	,,	,,
Nov. 1	6 10·1	2	18·2	F	,,
Dec. 7	6 3·3	1	16·0	...	,,
1891.					
June 17	15 23·3	3	13·7	mB	,,
July 4	14 22·1	2	11·9	,,	,,
Aug. 7	12 13·8	...	6·7	,,	,,
12	11 19·4	3	6·4	,,	,,
16	14 35·3	4	5·7	,,	,,
19	12 4·9	4	6·0	B	,,
28	14 22·2	4	2·7	mB	,,
29	10 16·8	3	4·8	,,	,,
Sept. 5	10 57	4	1·9	,,	,,
9	14 6·1	2	357·8	F	,,

Date.	G.M.T. of Transit.	Weight.	Longitude.	Brightness.	Observer.
1891.	h m		°		
Sept. 10	9 56	2	357·0	F	Williams.
12	11 35·7	2	358·1	mB	,,
22	9 40·5	est.	(352·2)	B	,,
27	8 57·6	3	358·0	mB	,,
Oct. 4	9 39·7	3	355·7	vB	,,
28	9 28	2	354·9	mB	,,
30	11 10·5	2	357·3	F	,,
Dec. 20	8 39·7	1	2·4	mB	,,
1892.					
July 7	14 35·3	3	352·4	,,	,,
Aug. 20	11 11	est.	(1·7)	,,	,,
21	16 48·8	2	356·3	F	,,
22	12 42·0	3	357·4	,,	,,
26	16 3·9	est.	358·5	,,	,,
31	14 52·9	4	349·7	mB	,,
Sept. 8	11 38·3	3	355·3	,,	,,
10	13 13	2	353·3	F	,,
15	12 17	3	351·4	vF	,,
17	13 55·8	2	351·9	F	,,
18	9 56	1	357·4	,,	,,
24	14 35·3	3	348·6	,,	,,
Oct. 2	10 59·8	1	341·7	vF	,,
6	14 12	2	339·5	,,	,,
7	10 1·1	3	338·2	F	,,
9	12 1·4	2	(351·7)	,,	,,
11	13 19·5	3	339·7	vF	,,
12	9 13·1	2	341·2	,,	,,
23	13 15	2	341·7	,,	,,
Nov. 7	10 27	3	335·4	,,	,,
24	9 34·8	3	338·8	,,	,,
27	7 4·2	2	338·5	,,	,,
Dec. 4	7 51·4	1	338·6	vF?	,,
6	9 30·4	2	338·8	eF	,,
11	8 43·9	2	341·8	,,	,,
13	10 21·8	est.	341·2	...	,,
21	6 53·8	est.	336·8	eF	,,
23	8 35·3	2	338·4	vF	,,
1893.					
Aug. 14	12 53·5	2	332·8	mB	,,
16	14 24·2	1	(328·1)	...	,,

Date.	G.M.T. of Transit.	Weight.	Longitude.	Brightness.	Observer.
1893.	h m		°		
Aug. 23	15 25·9	1	337·1	F	Williams.
28	14 31	est.	335·3	F?	"
Sept. 4	15 12	1	332·1	eF	"
Oct. 8	13 3·3	3	325·7	F	"
Nov. 6	12 4·5	1	331·6	vF	"

It will be seen from the foregoing list that the spot was under observation from 1885 January 27 to 1893 November 6, a period of 3205 days, or nearly nine years. Such a long duration is the more remarkable when it is considered that the spot was of comparatively small dimensions, its diameter, in fact, not much exceeding that of Satellite III.

The variations in the rate of motion of the spot are no less remarkable than its longevity. It is a very significant circumstance that none of these long-enduring spots have preserved a uniform motion. The great red spot even, it is well known, has varied considerably in its rate of motion from time to time. The present spot C is no exception to this rule. The following table gives its approximate period of rotation for each opposition, together with the number of rotations comprised between the first and last observation. The observations of 1886 are insufficient to give more than an approximate result, but the position of the spot in that year relative to that which it occupied in 1885 and in 1887 shows that its real rate of rotation in the opposition of 1886 probably differed little from what it was in the other two years :—

Opposition.	Rotation Period. h m s	No. of Rotations.	Opposition.	Rotation Period. h m s	No. of Rotations.
1885	9 55 32·3	348	1890	9 55 40·3	485
1886	(36·2)	58	1891	36·2	449
1887	32·	6280	1892	35·7	408
1888	38·8	362	1893	35·8	203
1889	43·7	468			

The following is a short history of the motion of the spot gathered from the foregoing table in conjunction with the previous list of observations. From 1885 January 27 to 1887 July 26 the motion was almost perfectly uniform, the rotation being performed in a period of $9^h\ 55^m\ 32^s{\cdot}5$. This rate of motion seems to have been continued almost up to the commencement of the observations of 1888, when a sudden check occurred, and the spot came nearly to a standstill with respect to Marth's zero meridian. This state of things continued almost unaltered all through the opposition of this year. In 1889 March we still find the spot in nearly the same longitude, but its motion then became still slower, so that the mean period of rota-

tion for the apparition was as long as $9^h\ 55^m\ 43^s{\cdot}7$. A slight increase, however, occurred in the velocity of the spot in 1890, whilst in 1891 a still further increase in velocity took place, the period of rotation diminishing to $9^h\ 55^m\ 36^s{\cdot}2$; and this accelerated rate of motion was maintained practically unaltered, though with temporary slight variations, in the two succeeding years. The spot was unfortunately lost sight of after 1893 November 6, owing to the enormous changes which were occurring in that year in the region of the north equatorial belt, changes which quite altered the aspect of this part of the planet in the course of a few months.

In connection with the probable cause of the arrestment of the spot's motion in 1888, it is necessary to consider the conditions prevailing along the whole zone in which it was situated. In 1887 a somewhat abnormal condition of affairs had prevailed along this zone. Whilst in one hemisphere of *Jupiter* the spots were rotating at an average rate of $9^h\ 55^m\ 41^s{\cdot}3$, in the other hemisphere the spots—amongst them our spot C—were rotating in $9^h\ 55^m\ 32^s{\cdot}2$.* It is obvious that such a state of things could not endure permanently if the two series of spots were at the same level, but that ultimately the swifter spots must overtake and collide with the more sluggish ones. This is exactly what appears to have happened, with the result that the motion of the swifter spots was arrested, and made to conform to that of the more sluggish ones. The velocity of the material of the zone consequently became nearly uniform right round the planet. Subsequently to 1889 the acceleration in velocity of spot C that then occurred seems to have affected more or less the whole zone.

An interesting point about the arrestment of the velocity of spot C is that it was not perfectly regular. There were obviously slight minor fluctuations from time to time in the position of the spot. Such fluctuations might well be expected to occur in the case of two opposed masses of material, possessed of differing velocities, coming into a state of equilibrium.

A few words should be said relative to the appearance of the spot. When at its greatest intensity it was a very brilliant object, appearing as a definite disc, slightly oval in shape, and rather larger than satellite III. But at other times, even when brilliant, it appeared quite indefinite, whilst on several occasions feebler extensions were seen in an east or west direction. It is probable that such variations in aspect are answerable for some of the discordances in the observations.

The fluctuations in the brightness of the spot, though considerable, were not nearly so great or so sudden as were those experienced by the white equatorial spot of 1880. It is probable, too, that some of the differences here recorded had an atmo-

* Further particulars concerning this anomalous state of things will be found in the writer's *Zenographical Fragments*, p. 18.

spheric origin. The visibility of very large spots, provided that they are not faint, is almost independent of the state of the seeing. But the smaller a spot may happen to be, the more is its visibility affected by poor definition. Such a spot as C would not be altogether obliterated by the worst and most confused seeing obtainable in practice, but it would certainly appear less conspicuous under such conditions.

Equatorial Comparisons of Neptune with 114 (o) *Tauri,* 1897 *December.* By John Tebbutt.

In consequence of illness and cloudy weather I found it impossible to obtain earlier comparisons than those which accompany this letter. The observing conditions were, however, excellent on each evening, and the measures were made with the filar micrometer on the 8-inch equatorial and in a bright field. Each coordinate of the planet is the result of twenty comparisons. The mean place of the star for 1897·0 is derived from the following Catalogues: Washington, 1860, 3rd ed.; Radcliffe, 1860–1890; Glasgow, 1870; and Greenwich, 1864, 1872, 1880. The precessions with the secular variations have been employed from the Radcliffe Catalogue, 1890, with checks from the same elements in the Greenwich Catalogue, 1880, and the annual proper motions in R.A. and N.P.D. have been adopted as $-0^{s}\cdot0011$ and $-0''\cdot006$. By assigning equal weights to the Catalogues the mean place for 1897·0 is R.A. $= 5^{h}\ 21^{m}\ 26^{s}\cdot88$ N.P.D. $= 68^{\circ}\ 9'\ 4''\cdot3$. The star is also one of Professor Newcomb's Standard Clock and Zodiacal stars.

In the last column of the accompanying table will be found a comparison of the observed places with the transit ephemeris on page 281 of the *Nautical Almanac*. The *Nautical Almanac* does not furnish any semidiameter for the planet, but the *American Ephemeris* assigns $1''\cdot3$ for the time of opposition. This value must, I think, be much too great.